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Implementation of Reconfigurable, Planar Meander Antenna for WLAN Applications

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Abstract

This paper presents the implementation of Reconfigurable, Planar Meander Antenna operates at 2.45 GHz and 5.12 GHz for WLAN applications. In the proposed work, the planar meander antenna has the dimension footprint of 35×55 mm^2 with the size of the radiating element as 15.5×17mm^2 over FR4 substrate. Also, varactor diodes are incorporated in the appropriate arm of the proposed meander antenna to achieve frequency reconfigurability. The principle of reconfigurability in meander antenna focuses size reduction and dual band operations. A parametric study is done for finding the resonance in the appropriate arm positions of the meander antenna for the appropriate optimization. The characterization of the proposed antenna without and with varactor diodes are carried out, and the results are compared. The proposed antenna design is validated for its concurrence in both simulation and experimentation. The reflection coefficient attained for antenna with varactor is -23.66dB and -18.41dB at 2.45 GHz and 5.1 GHz, respectively. The directivity of the proposed meander antenna without varactor diodes is 2.143 dBi at 2.45 GHz and 4.829 dBi at 5.12 GHz, respectively. Similarly, for the antenna with the varactor diode is 2.066 dBi at 2.45 GHz and 6.097 dBi at 5.12 GHz, respectively.The overall size of the meander antenna is reduced by 76%. VSWR of the proposed antenna is approximately 1.

Keywords: *Meander antenna; Reconfigurability; Varactor diode; Dual band; Frequency tuning, Reflection coefficient*

1. Introduction

Meander antenna is electrically small antenna. It is an extension of the basic folded antenna. The folded antennas are operating at lower frequencies, than resonances of a single element antenna of the equal length. These folded antennas are used for high input impedances when compared with the conventional antennas. Thereby, the meandered antennas are constructed using asymmetric or symmetric patterns with higher input impedances. The meandered antennas are designed using various arm lengths based on the behavior of its resonances. More complex geometrics are adapted for the construction of meandered antennas. These structures are characterized and optimized by appropriate EM simulators. Hence, the meander structures are more compact in size with enhanced performance. This paves the way to construct meandered array antenna.

For compact wireless system, the integration of numerous antennas is avoided through the utilization of reconfigurable antennas. This significantly reduces the complexity of the wireless

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system without affecting the performance of the same. The reconfigurability of an antenna is achieved through changing the frequency, polarization behavior, and E field, H field characteristics. These parameters are highly influenced by the current distribution of the radiating structure. The current in an antenna can be changed by deploying p-i-n diodes, varactor diode, MEMS, and liquid crystal materials. The alteration in the field distribution of the antennas is achieved by the currents in the effective aperture of the antenna. Thus, the redistribution of the fields is used for reconfiguration. The two terminal active devices integrated with the radiator can be loaded either in the radiating element or on the feed network of the radiator. If the integration of the two terminal devices on the radiating element is incorporated, then there is a significant change in the structure of the radiating element. On the other hand, if the two terminal devices are incorporated in the feed element of the radiating element, there is a change in the function of the radiating element. In the proposed work, the varactor diode is used as the two terminal device and it is loaded in the radiating element for the switching function. Here, the switching function of the proposed reconfigurable antenna can operate in low frequency mode (2.45 GHz) and high frequency mode (5.12 GHz).

In Awl et al. (2021), the authors have proposed a patch with double meander dipole antenna array which resonates between 12 and 18 GHz to achieve the bandwidth of 5.2 GHz and peak gain of 10 dB, using double layer substrate technique. The authors in Islam et al. (2019), have reported an inverted S-shaped meander microstrip patch antenna that operates at 2.4 GHz for IoT environment. The enhanced bandwidth of 12.5% and 79% radiation efficiency is achieved in Islam et al. (2019). A planar loop antenna is designed and reported in Chen et al. (2016), which operates between 922 and 928 MHz for UHF-RFID application. In Chen et al. (2016), a circularly polarized radiation is attained using a gap between the meandered loop. Chen et al. (2017) have reported a meander antenna with capacitive load that uses inductive feeding technique. The peak gain of 10.19 dB and bandwidth of 7.23% is achieved in Chen et al. (2017). In Alqadami et al. (2021), a flexible meander line antenna array with 16 element is proposed for wearable imaging application. The meander array in Alqadami et al. (2021) operates between 0.45 and 3.6 GHz, attaining a fractional bandwidth of 155%. In Khaleghi (2007), Khaleghi proposed a meander line antenna with a tapered ground plane and a back coupled rectangular patch operating for dual band viz. 2.4-2.48 GHz and 5.15-5.35 GHz for WLAN application. The shaped ground plane is used for impedance matching for the first resonance and the rectangular patch is responsible for the even mode resonance in Khaleghi (2007) which results in the bandwidth of 11% and 6% for respective resonance. In Lee et al. (2014), the authors have proposed a folded meander line for miniaturizing a chip antenna to improve its performance. The chip antenna proposed in Lee et al. (2014) resonates at 2.45 GHz and 2.73 GHz. In Naidu et al. (2019), the authors have proposed a meander shaped antenna fed using asymmetric coplanar strip (ACS) operates for dual band like 2.5 to 2.7 GHz and 4.6 to 6.1 GHz with bandwidth of 200 MHz and 1500 MHz for WiMAX and WLAN application. The properties and design parameters are investigated and studied from Ambhore and Dhande (2012). The design of meander antenna operating at 2.5 GHz is studied from Manchanda et al. (2014).

Thus, from the study of literatures, the dimension of meander antenna plays a pivotal role. In this paper, a reconfigurable meander antenna for WLAN application is designed and implemented. The rest of the manuscript is organized as follows, Section 2 presents the design of meander antenna with parametric study. Section 3 details the meander antenna with varactor diode for reconfigurability and its performance evaluation. The fabricated and the measured characteristics are discussed for meander antenna with and without varactor diode in Section 4 whereas, Section 5 concludes the research presented in this paper.

Table 1. Geometry of the proposed meander line antenna

Parameter	L	W	$L1$	$W1$	$L2$	$W2$	$W3$	$W4$	$W5$	$L3$	$L4$	g
Dimension(mm)	35	55	6.5	53	8	2	9	4.5	7.5	3	5	1

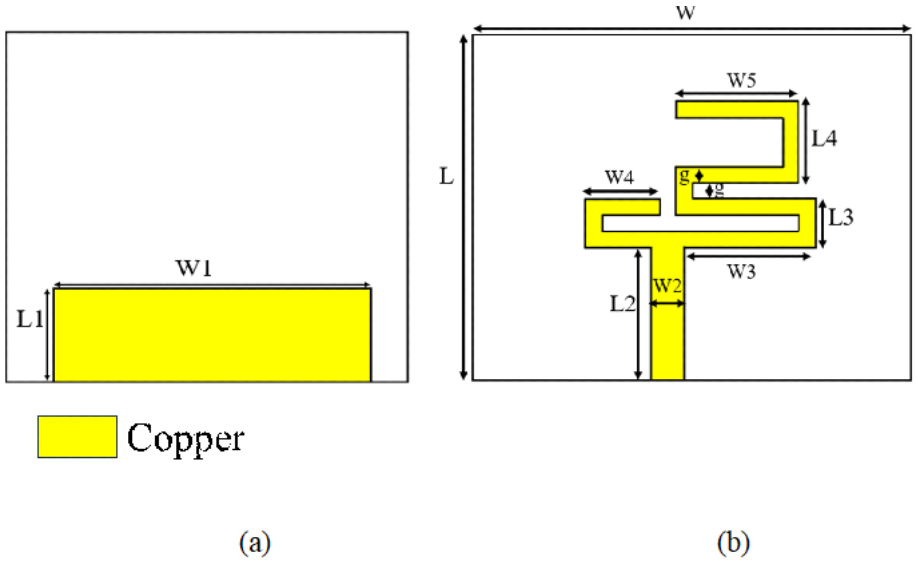

Figure 1. Structure of meander antenna (a) rear view (b) front view

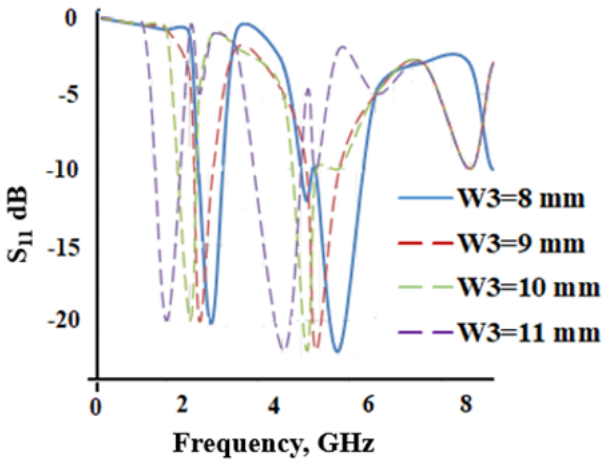

Figure 2. Parametric study of meander antenna for various arm length (W3)

2. Design of Meander Antenna

2.1. Geometry

This section presents the design of the proposed meander antenna for S and C band and its S parameter characteristics. Meander antenna is an electrically small antenna. Electrically small antennas have several issues that includes narrow bandwidth, high VSWR, low benefit and excessive pass polarization levels. The meander antenna consists of series of vertical and horizontal elements with spacing between them. The meander antenna is considered as LC circuit for the equivalent model. In a meander antenna, the vertical element is considered as inductor, whereas the horizontal element is considered as capacitor. Figure 1 shows the design of proposed meander antenna with three arms. The proposed meander antenna is designed using the substrate lossy FR4 whose dielectric constant 4.3 and thickness of 1.6 mm, whose dimension is $L \times W$. The partial ground is placed on the bottom of the substrate with the dimension of $L1 \times W1$ using copper. The conducting layer is designed as a meander pattern with three arms above the substrate as shown in Fig.1 (b). The design of meander antenna consists of mixed horizontal and vertical lines. The increase in the number of turns in the meander increases the performance of the antenna Jahanbakhshi et al. (2012). Similarly, the increase in spacing between the meander decreases the

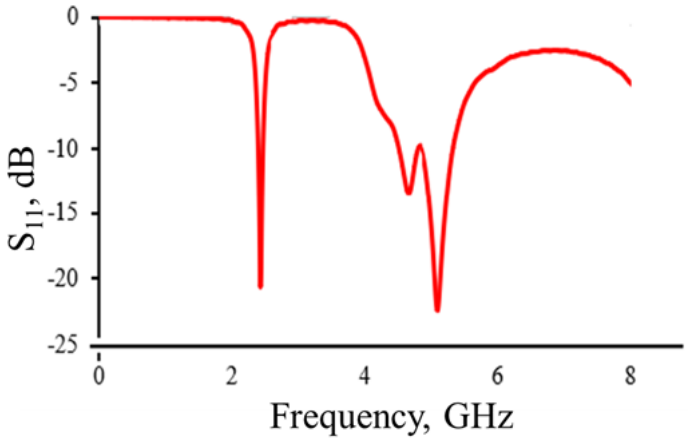

Figure 3. Reflection coefficient of the proposed meander antenna

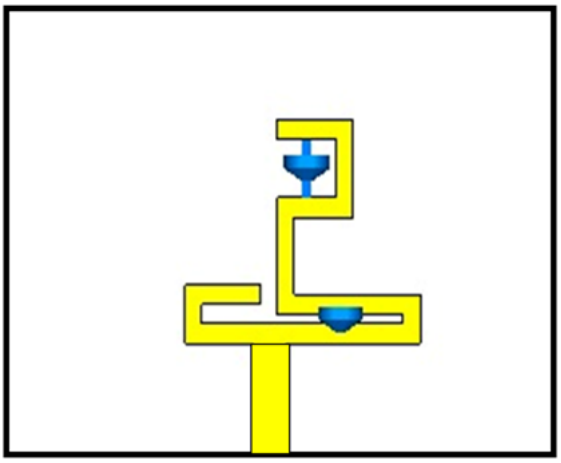

Figure 4. Structure of dual band meander antenna with varactor diode

resonant frequency. Thus, the challenge behind the design of meander antenna is to achieve the resonant frequency with an optimum number of turns with compact size. The optimized dimensions of the proposed meander antenna are given in the Table 1.

2.2. Parametric study

To study the impact of arm length in the design of meander antenna, the parametric analysis is carried out. W3 is the length of the part of the arm as shown in Fig.1 (b). Thus, the proposed meander antenna is simulated for different values of W3 and is listed in the Table 2. Figure 2 shows the analysis of reflection coefficient (S_{11}) for different arm lengths. The arm length is optimized between 8 mm and 11 mm. The characteristics results with raise in the arm length shift the operating frequency (f_r) of dual bands to the lower frequencies along with the reduction in the reflection coefficient (S_{11} in dB) Islam and Roy (2023). At the length of 9 mm, the resonant frequency is matched with desired frequencies, such as 2.45 GHz and 5.1 GHz. With this optimization, the length of the meander antenna arm is characterized for the appropriate frequencies. Similarly, the other parameters of the proposed meander antenna are optimized and the dimensions of the geometry is given in Table 1 with the reflection coefficient curve in Fig. 3.

Table 2. Optimization of the length of the arm (W3)

W3(mm)	1^{st} **Band**		2^{nd} **Band**	
	$f_r(GHz)$	$S_{11}\ dB$	$f_r(GHz)$	$S_{11}\ dB$
8	2.6	-20	5.6	-22
9	2.4	-19.75	5.1	-21.8
10	2	-19.70	4.5	-21.5
11	1.5	-19.50	4	-21

3. Meander Antenna with Varactor Diode

The structure of the proposed dual band meander antenna with varactor diode is shown in Fig. 4. The varactor diodes are integrated with the meander antenna for its reconfigurability. The varactor diode has variable capacitance. Hence, the current is controlled by placing varactor diode in the appropriate antenna arm of the antenna for tuning. By changing the capacitance of the varactor, the resonant frequency, radiation pattern and impedance matching are varied for the desired range of values. The proposed dimension of the meander antenna without varactor diode is optimized further to obtain the resonator with the desired operating frequencies with the maximum return loss. Thus, the revised dimensions for the resonator with the varactor diode are L2 – 6 mm, W2 – 46 mm, and W5 – 2.5 mm, respectively. The characteristic of reflection coefficient for the designed meander antenna with varactor diode is shown in Fig. 5. The meandered resonator with the varactor diode resonates at 2.45 GHz and 5.14 GHz with minimum reflection coefficient of -15 dB.

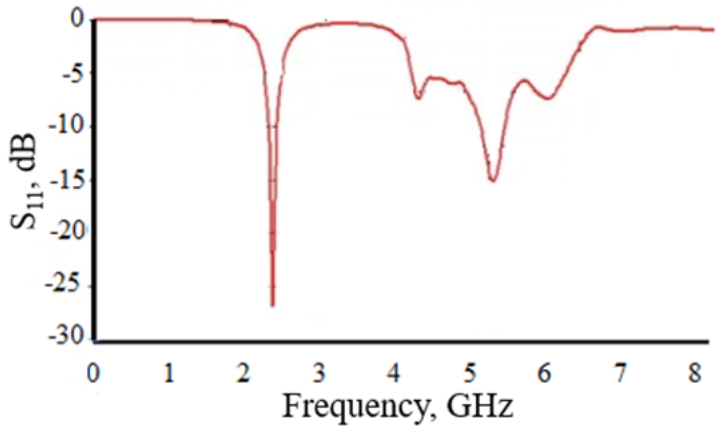

Figure 5. Reflection coefficient of the proposed meander antenna with varactor diode

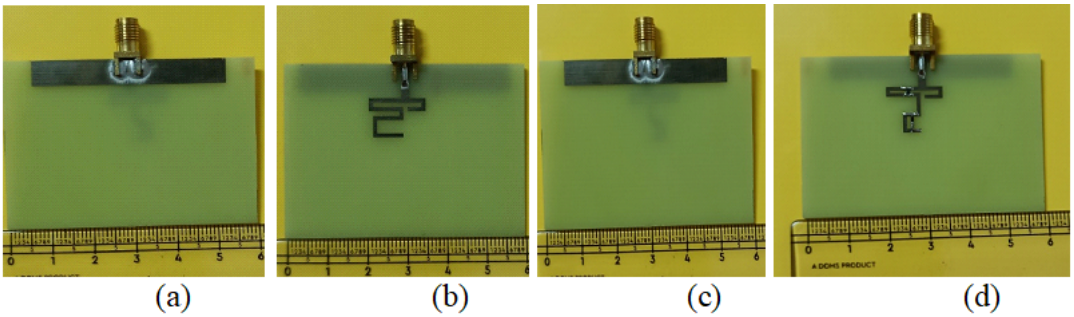

Figure 6. Photograph of fabricated meander antenna (a,b) without varactor diode (c,d) with varactor diode

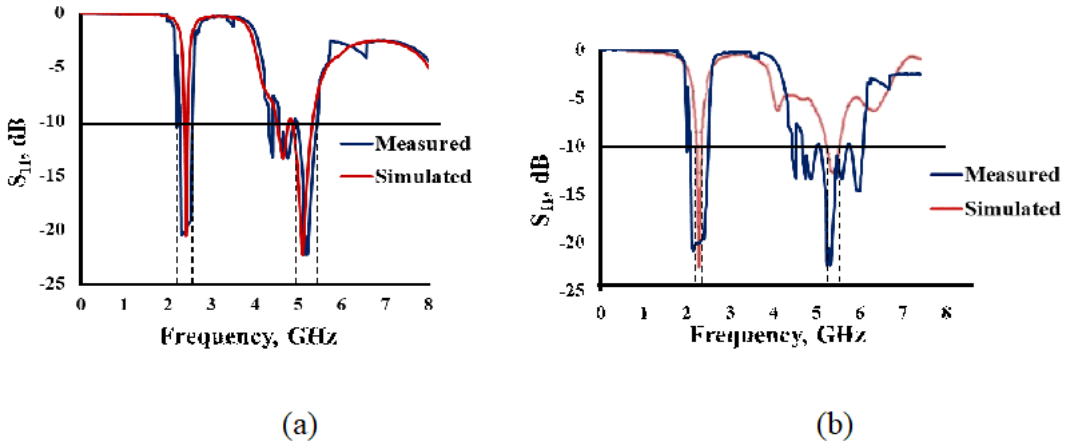

Figure 7. Simulated and measured reflection coefficient for the proposed meander antenna without varactor diode

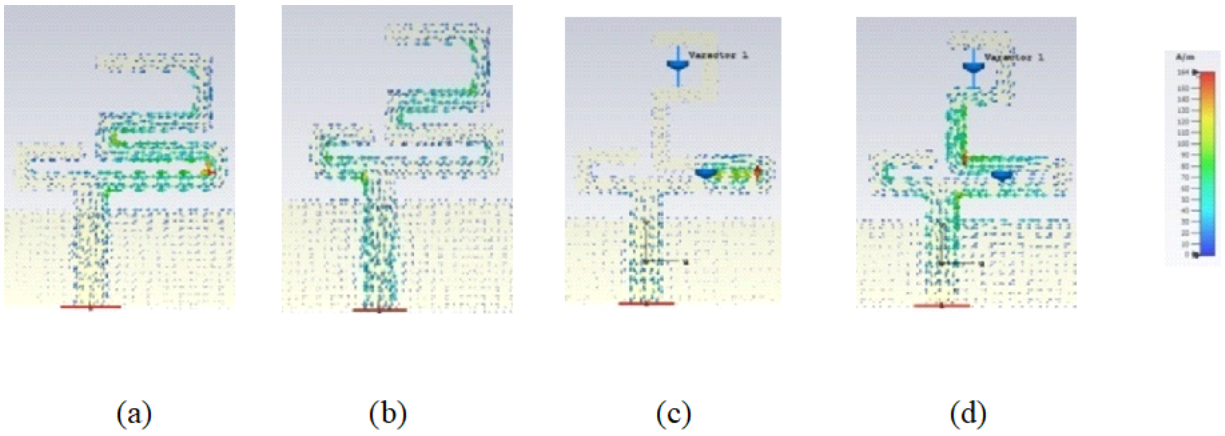

Figure 8. Surface current density for meander antenna (a) without varactor at 2.45 GHz, (b) without varactor at 5.12 GHz, (c) with varactor at 2.45 GHz and (d) with varactor at 5.12 GHz

4. Measurement of Meander Antenna (With and without Varactor Diode)

The designed meander antenna without and with the varactor diode is fabricated and the measured reflection coefficient is discussed in this section. Fig. 6 (a) and 6 (b) shows the photograph of the rear and front view of the fabricated meander antenna without varactor diode, respectively. Figures 6 (c) and 6 (d) depicts the photographs of the rear view and front view of the dual band meander antenna with varactor diode, respectively. The meander antenna with the varactor diode operates at 2.45 GHz and 5.12 GHz with reconfigurability. When it comes to WiFi coverage, 2.4 GHz outshines 5 GHz. In the 2.4 GHz band, the lower frequencies that can be transmitted right here can more effortlessly penetrate solid objects that means the signal can be carried out throughout the living area Ibrahim et al. (2022). The optimum frequency 5 GHz is much suitable for high-speed WiFi than 2.4 GHz. To compare the 2.4 GHz band will aid speeds among 450 Mbps and 600 Mbps, while 5 GHz will aid speeds of up to 1300 Mbps. When considering the reality that WiFi standard 802.11n has been round for almost a decade now, the general public of our wireless technologies have been built to support each the 2.4 GHz and 5 GHz bands.

Simulated and measured reflection coefficient for the proposed meander antenna without and with varactor diode is shown in Fig. 7, respectively. The simulated bandwidth of the meander antenna without varactor diode in Fig.7 (a) is 0.0848 GHz at 2.45 GHz and 0.4878 GHz at 5.12

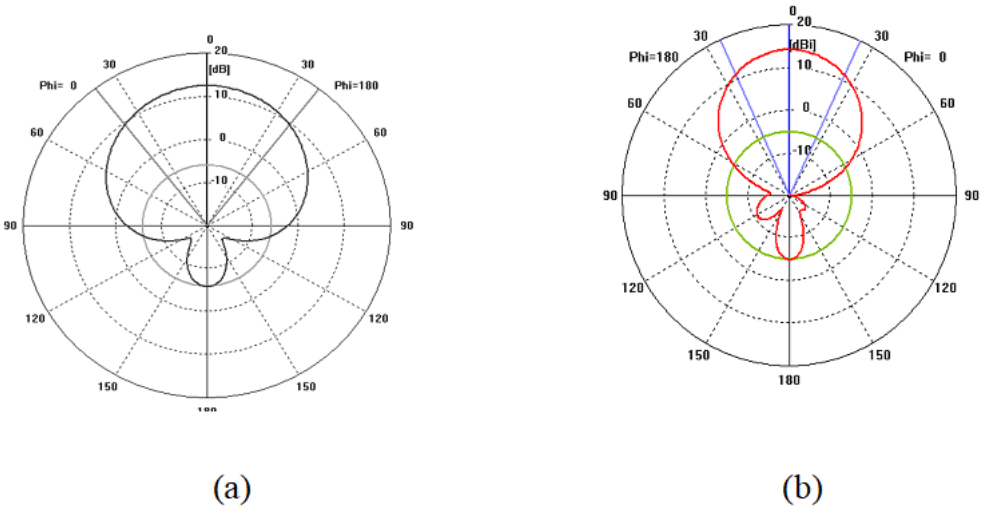

Figure 9. Simulated radiation pattern of meander antenna (a) without varactor and (b) with varactor

GHz. Similarly, the simulated bandwidth of the antenna with varactor diode (Fig.7 (b)) is 0.0955 GHz at 2.45 GHz and 0.5132 GHz at 5.12 GHz. The bandwidth is verified in measurement.

Table 3. Comparison of the proposed antenna with other literatures

Parameters/ References	**Awl et al. (2021)**	**Chen et al. (2016)**	**Alqadami et al. (2021)**	**Naidu et al. (2019)**	**Proposed Work**	
Description of Antenna	Meander dipole	Meander Loop	Meander Line	Meander antenna	Meander without varactor diode	Meander with varactor diode
Tuning/Not Tuning	No Tuning	No Tuning	No Tuning	No Tuning	Tuning	Tuning
Size (mm)	23.45 × 23.45	58.6 × 58.6	24 × 45	10 × 19	20 × 30	20 × 30
Substrate & Dielectric constant	RT Duroid/ 2.2	FR4 / 4.4	Silicon / 11.7	FR4 / 4.4	FR4 / 4.4	FR4 / 4.4
Operating Frequency (GHz)	11.5 & 15.5	0.925	0.45-3.6	2.5 & 5	2.5 GHz & 5.12 GHz	2.5 GHz & 5.12 GHz
% Bandwidth	30	2.92	155	200	3.46 & 9.52	3.97 & 10.06
Reflection Coefficient (dB)	-27 &-22	-18	-22	-22	-21.66 &23.4	-23.66 &18.41
Return loss (dB)	28.62 &-26.85	-25.1	-26.85	-25	-26.68 & 27.38	-27.48 & 25.3
VSWR	1	1	1	1	1 & 1	1 & 1
Directivity (dBi)	7.9	1.73	NA	NA	2.14 & 4.82	2.06 & 6.09

The surface current density for the proposed meandered antenna is shown in Fig. 8 for dual

operating bands, such as 2.45 GHz and 5.12 GHz. Fig. 8 (a) depicts that the surface current is accumulated at the arms of the meander resonator without varactor diode at lower frequency of 2.45 GHz. Although Fig. 8 (b) shows that the maximum surface current density is placed on the upper and the smallest arm of the proposed meander at 5.12 GHz. Similarly, the surface current density for meander antenna with varactor diode is shown in Fig. 8 (c) for 2.45 GHz and Fig. 8 (d) for 5.12 GHz.

The radiation pattern for the proposed meander antenna for without and with varactor diode is shown in Fig. 9. The directivity of dual band meander antenna is 2.143 dBi at 2.45 GHz and 4.829 dBi at 5.12 GHz. Similarly, for the antenna with the varactor diode achieves the directivity of 2.066 dBi at 2.45 GHz and 6.097 dBi at 5.12 GHz. Thus, the proposed antenna can be used for the purpose of transmission using reconfigurability at dual bands. The proposed meander antenna is compared with other literature's in Table 3.

5. Conclusion

A reconfigurable meander antenna is presented in this research that operates for dual band viz., 2.45 GHz and 5.12 GHz. The proposed antenna is fabricated on FR4 substrate with the dimensions of $35mm \times 55$ mm. The reconfigurable meander antenna is designed and fabricated with the help of varactor diode for WLAN application. The parameters used for the geometry of the antenna are optimized to achieve better reflection coefficient and radiation characteristics. Thus, the variation in the length of the meander line changes the operating frequencies. The measured results of the fabricated reconfigurable meander antenna show a good agreement with the simulated results. Henceforth, the proposed antenna is well suited for WLAN applications.

References

Alqadami, A. S; Stancombe, A. E; Bialkowski, K. S, and Abbosh, A. Flexible meander-line antenna array for wearable electromagnetic head imaging. *IEEE Transactions on Antennas and Propagation*, 69, 2021. ISSN 15582221. doi: 10.1109/TAP.2020.3037742.

Ambhore, V. B and Dhande, A. P. An overview on properties, parameter consideration and design of meandering antenna. *International Journal of Smart Sensor and Adhoc Network.*, 2012. doi: 10.47893/ijssan.2012.1138.

Awl, H. N; Mahmud, R. H; Karim, B. A; Abdulkarim, Y. I; Karaaslan, M; Deng, L, and Luo, H. Double meander dipole antenna array with enhanced bandwidth and gain. *International Journal of Antennas and Propagation*, 2021, 2021. ISSN 16875877. doi: 10.1155/2021/9936781.

Chen, H. D; Sim, C. Y. D; Tsai, C. H, and Kuo, C. Compact circularly polarized meandered-loop antenna for uhf-band rfid tag. *IEEE Antennas and Wireless Propagation Letters*, 15, 2016. ISSN 15361225. doi: 10.1109/LAWP.2016.2518215.

Chen, J. H; Yang, C. K; Cheng, C. Y; Yu, C. C, and Hsu, C. H. Gain enhancement of a compact 2.4-ghz meander antenna using inductive feed and capacitive load. *Microwave and Optical Technology Letters*, 59, 2017. ISSN 10982760. doi: 10.1002/mop.30784.

Ibrahim, H. H; Singh, M. J; Al-Bawri, S. S; Ibrahim, S. K; Islam, M. T; Soliman, M. S, and Islam, M. S. Low profile monopole meander line antenna for wlan applications. *Sensors*, 22, 2022. ISSN 14248220. doi: 10.3390/s22166180.

Islam, M. S; Islam, M. T; Ullah, M. A; Beng, G. K; Amin, N, and Misran, N. A modified meander line microstrip patch antenna with enhanced bandwidth for 2.4 ghz ism-band internet of things (iot) applications. *IEEE Access*, 7, 2019. ISSN 21693536. doi: 10.1109/ACCESS.2019.2940049.

Islam, T and Roy, S. Low-profile meander line multiband antenna for wireless body area network (wban) applications with sar analysis. *Electronics (Switzerland)*, 12, 2023. ISSN 20799292. doi: 10.3390/electronics12061416.

Jahanbakhshi, A; Moradi, G, and Shirazi, R. S. Design and simulation of different types of meander line antennas with improved efficiency. 2012.

Khaleghi, A. Dual band meander line antenna for wireless lan communication. *IEEE Transactions on Antennas and Propagation*, 55, 2007. ISSN 0018926X. doi: 10.1109/TAP.2007.891873.

Lee, M. W; Leung, K. W, and Chow, Y. L. Low cost meander line chip monopole antenna. *IEEE Transactions on Antennas and Propagation*, 62, 2014. ISSN 0018926X. doi: 10.1109/TAP.2013.2287518.

Manchanda, S; Hatwar, M, and Abhishek, B. Design of meander line antenna for operating frequency of 2. 5 ghz. *International Journal of Computer Applications*, 93, 2014. doi: 10.5120/16470-6188.

Naidu, P. V; Kumar, A, and Rajkumar, R. Design, analysis and fabrication of compact dual band uniplanar meandered acs fed antenna for 2.5/5 ghz applications. *Microsystem Technologies*, 25, 2019. ISSN 09467076. doi: 10.1007/s00542-018-3937-8.